DOCUMENT RESUME

ED 481 345 CE 085 556

AUTHOR	Savill-Smith, Carol; Kent, Phillip
TITLE	The Use of Palmtop Computers for Learning: A Review of the Literature.
INSTITUTION	Learning and Skills Development Agency, London (England).
SPONS AGENCY	Learning and Skills Council, Coventry (England).
ISBN	ISBN-1-85338-862-9
PUB DATE	2003-00-00
NOTE	50p.; Additional support from the Commission of the European Communities, Directorate-General for the Information Society.
CONTRACT	IST-2000-25270
AVAILABLE FROM	Learning and Skills Development Agency, Regent Arcade House, 19-25 Argyll Street, London W1F 7LS, United Kingdom (Ref. No. 1477). Tel: 020 7297 9000; Fax: 020 7297 9001; Web site: http://www.lsda.org.uk/home.asp. For full text: http://www.lsda.org.uk/files/pdf/1477.pdf.
PUB TYPE	Information Analyses (070)
EDRS PRICE	EDRS Price MF01/PC03 Plus Postage.
DESCRIPTORS	Access to Education; Cognitive Style; Computer Software Selection; *Computer Uses in Education; Distance Education; Educational Games; Educational Resources; Educational Technology; Foreign Countries; Informal Education; Information Technology; *Instructional Innovation; *Instructional Material Evaluation; *Literacy Education; Literature Reviews; *Material Development; Nontraditional Education; Numeracy; *Out of School Youth; Technology Planning
IDENTIFIERS	Europe; *Handheld Computers; Personal Digital Assistants

ABSTRACT

The m-learning project is a 3-year, pan-European research and development study which aims to use portable technologies to provide learning experiences relating to literacy and numeracy skill development for young adults aged 16-24 who are outside full-time formal education settings, and to promote the development and achievement of lifelong learning objectives. The use of palmtop, or handheld, computers is rapidly increasing in the developed world. In conjunction with the m-learning project, a literature review was conducted to find information relating to the use of palmtop computers and to assist with the selection of appropriate technologies emerging in the field and the design and development of learning materials. There are several reasons to use palmtop computers for learning, including that they are inexpensive; they offer ubiquitous computing; they develop information literacy; and they promote collaborative and independent learning. In addition, there are issues that make their use problematic, such as a lack of relevant educational content and competing and incompatible operating systems. The following topics should be taken into account in future research and design activities: (1) information literacy; (2) design of both collaborative and independent learning activities; (3) game-playing and learning; (4) use of palmtop computers for activities outside the traditional classroom; (5) reflective logs and blogging; and (6) guidelines for the design of interfaces and the presentation of material on handheld devices. (Contains an appendix describing methods used for finding research studies, a glossary, and 71 references.) (MO)

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The use of palmtop computers for learning

A review of the literature

Carol Savill-Smith
and Phillip Kent

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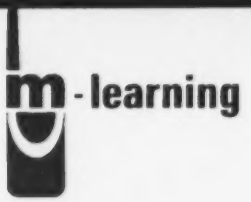

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Acknowledgements

We would like to thank Jill Attewell, the Learning and Skills Development Agency m-learning programme manager, for her support, advice and contribution to the editing process, and Helen Rendell for assisting with the identification of research material for this review.

Published by the Learning and Skills Development Agency

www.LSDA.org.uk

Feedback should be sent to:
Information Services
Learning and Skills Development Agency
Regent Arcade House
19–25 Argyll Street
London W1F 7LS.
Tel +44 (0) 20 7297 9144
Fax +44 (0) 20 7297 9242
enquiries@LSDA.org.uk

Registered with the Charity Commissioners

Printed in the UK

1477/08/03/2400

ISBN 1 85338 862 9

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Further information

For further information about the issues discussed in this publication please contact:
Jill Attewell
m-learning Programme Manager
Learning and Skills Development Agency.
Tel +44 (0) 20 7297 9100
jattewell@LSDA.org.uk

This publication was supported by the Learning and Skills Council as part of a grant to the Learning and Skills Development Agency for a programme of research and development. The m-learning project is also supported by the European Commission Directorate-General Information Society (IST-2000-25270).

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PREFACE

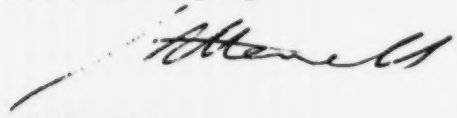
The use of palmtop, or handheld, computers is rapidly increasing in the developed world. In the past many of these devices have been simply standalone small computers, running relatively simple programs but with the added feature of mobility. Now many palmtop computers have more sophisticated uses, usually running compact editions of the main office applications, such as word processing and spreadsheets, with larger memory capacities, a variety of data input devices and the ability to link into wireless networks. Palmtops can also act as communication devices, by incorporating a mobile phone (cellphone) card, and entertainment devices by including computer games.

This research report is the result of a literature review conducted by the Learning and Skills Development Agency during the m-learning project. The focus is on research involving the use of palmtop computers for learning. The motivation for this review is to inform the design and development of mobile learning materials and systems and to inform the project's research activities. This report highlights many interesting pedagogic and technical issues, which makes it a useful reference for teachers, trainers, developers, researchers and others with an interest in mobile learning.

The m-learning project is a 3-year, pan-European research and development study with partners in Italy, Sweden and the UK. Its aim is to use portable technologies to provide learning experiences relating to literacy and numeracy skill development for young adults aged 16–24 who are outside full-time formal education settings, and to promote the development and achievement of lifelong learning objectives. The m-learning project is coordinated by the Learning and Skills Development Agency and its project partners include two commercial companies and two universities based in three European countries:

- Cambridge Training and Development Limited, United Kingdom
- Centro di Ricerca in Matematica Pura ed Applicata – the Centre for Research in Pure and Applied Mathematics at the University of Salerno, Italy
- Learning and Skills Development Agency, United Kingdom
- Lecando AB, Sweden
- Ultralab, Anglia Polytechnic University, United Kingdom.

Further information about the m-learning project can be found at www.m-learning.org



Jill Attewell
m-learning Programme Manager
Learning and Skills Development Agency

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1 INTRODUCTION AND OVERVIEW OF THE LITERATURE

A review of the published literature relating to the use of palmtop computers for learning was required by the m-learning project. It was needed to inform the project partners about various matters relating to their use, such as current pedagogy, and to assist with the selection of appropriate technologies in an emerging field, the design and development of learning materials, and also with the underpinning research. The following research questions guided this review.

- How have palmtop computers been used for learning?
- What are young adults' experiences of using palmtop computers?

Because the aim of the m-learning project is to use mobile technologies to try to re-engage young adults (aged 16–24) in learning and to start to change their attitudes to learning and improve their life chances, the m-learning partners also wished to find out if studies had been conducted using palmtop computers with young adults who have:

- literacy, numeracy and other basic skill needs
- social and behavioural issues relating to youth education.

This research review synthesises the key messages from the current literature base of about 140 items, mostly written between 1999 and 2003. The main categories of information sourced have been found to be general overviews of the potential of palmtops for education, surveys of available technologies and software, and brief descriptions of largely school- or university-based research trials.

There was a notable lack of detailed, or comparative, research studies of projects and trials using handheld technologies. Some information appears to be more easily available on project websites and so has been included but, of course, such items will not have been academically reviewed. The largest area reporting research was medicine, with medical students becoming major users of palmtops because their learning involves placements in hospitals and community surgeries where they need to access clinical information and record their experiences for later reflection and assessment. Physicians also use palmtops as clinical organisers to make evidence-based decisions.

None of the items reviewed examined the use of handheld computers by the target audience of the m-learning project, ie disengaged young adults aged 16–24, but many items are still informative and may be useful to those considering implementing mobile learning with young people. Quotations from teachers and students using handheld computers have been included to illuminate the quality of people's experiences.

The generic term 'palmtop computers' encompasses the following types of computer technology (a glossary of specialist terms can be found at the back of this report):

- palmtop computers (eg the Psion palmtop computer)
- personal digital assistants, or PDAs (eg the PalmOS®)
- PocketPC-based handheld computers
- some specialised handheld devices: e-book readers, dictionaries and spell-checkers, graphical calculators.

This review takes place during a period of rapid change in the palmtop computer and mobile phone market. On the one hand, mobile phones are increasingly being designed with extra PDA-type facilities and other facilities such as a camera and picture messaging. These are often referred to as 'smart phones'. On the other hand, palmtop computers are becoming hybrid devices with mobile phone functionality. Although it is difficult to predict the future, Smith (2003) suggests that in the next 3 years mobile phone use by younger students will migrate to smart phones, whereas PDAs or phone-enabled PDAs will not be popular except where they support specialist courses. Smith also suggests that the newly released Tablet PCs will remain a niche market. It does seem possible, therefore, that this review will have relevance for people working with both types of technology (PDA and mobile phones) in the near future.

> *I wonder why we missed an opportunity to increase the learning potential of mobile phones. We would not have any problem convincing the students to use them. The PDA could go the same way. The potential for it to be a multi-functional device that students can take total ownership of and which has endless 'communication' applications is surely something we want?*
>
> Ron Hinshaw, Hermitage School, quoted in Perry 2003

This research report has not reviewed in depth the associated areas of mobile phones and computer games, as these are the subject of separate LSDA publications.

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2 USING PALMTOPS IN LEARNING

2.1 Why use palmtop computers for learning?

It is claimed that handheld computers are at the forefront of the fourth wave in the evolution of technology (Pownell and Bailey 2001). In the first wave computers were large, expensive mainframes, which were used in education to make administration and managerial tasks easier. The second wave started with the advent of desktop computers in the 1970s, where computers became 'personal' and schools introduced computer literacy courses for students to learn about the technology and how to use it. The third wave in the 1990s was characterised by the development of the internet and worldwide web, which highlighted electronic communication and collaboration. The fourth wave was said to be just beginning in 2001 and involves very small computers and wireless connectivity delivering 'anyone, any time, anywhere learning'.

The main reasons given for using palmtop computers for learning are that they assist students' motivation, help organisational skills, encourage a sense of responsibility, help both independent and collaborative learning, act as reference tools, and can be used to help track students' progress and for assessment. The following synopsis of the studies elaborates on these reasons.

2.1.1 Palmtops are relatively *inexpensive*, compared with full-sized desktop and laptop computers

The relatively low cost of palmtop computers makes it feasible to provide every student with a personal machine, thus offering 'ownership' of the computer and continuous access in and out of the formal setting of the school or college. A disadvantage of using palmtops is that they have less functionality than desktop computers. However, it is argued that without one-to-one and continuous access to computers for both teachers and students, the long-standing problems of the integration of computers into education will continue (Robertson *et al.* 1997). According to Soloway *et al.* (2001), personal computers have changed how professionals conduct their 'knowledge work', making them more productive and effective, but they have singularly failed to revolutionise schools (particularly at grade level K-12, which is defined by them as for students aged 6–18). They suggest that a fundamental problem is that students (and often teachers) have not, up to now, had anything like 'personal' access to networked desktop computers. The potential for ubiquitous 'ready-at-hand' palmtops to change this situation is great; there is mounting evidence that daily, pervasive use of computing leads to increased learning (Soloway *et al.* 2001). Palmtops support flexible 'cycles of doing and reflecting' (not tied to infrequent, timetabled access to a computer laboratory) and collaboration and sharing (especially via infra-red 'beaming' between palmtops). However, both these aspects pose the challenge of revising the curriculum to exploit them.

There is also some evidence that palmtops are easier to use than desktops:

> *[T]he majority of pupils had mastered the basics within 10 minutes ... pupils seem to remember the procedures for using the applications far more easily than those on a PC. Possibly their size and comparative simplicity makes them less daunting – more like a Gameboy™ [a portable handheld games console] perhaps?*
>
> Graham 1997

The results of a recent UK schools trial (Perry 2003) also suggest that students adapt quickly and enthusiastically to palmtops.

2.1.2 Palmtops offer the possibility of *ubiquitous computing*

Ubiquitous computing is an approach to human–computer interaction, generally attributed to Mark Weiser (1991) at Xerox PARC in the 1980s. It is often used to describe the situation where technology becomes virtually invisible in our lives, eg instead of having to use a fixed desktop computer, or a laptop computer, we will use technology embedded in the environment. The generally recognised goal of ubiquitous computing is thus to bring the user into central focus in a computing environment.

Palmtops can be used anywhere inside an educational institution, or outside, for example on field trips (this is particularly important for science learning). Inkpen (1999) points out that handheld technologies can provide access to computing at the places where children's activities and learning occur, unlike desktop computers which are often segregated from other learning activities in the classroom. Flexible access means opportunities to integrate learning technology into children's daily activities (eg the success of handheld toys like Gameboy™ and Tamagotchi™), where the products themselves become part of the children's culture.

One vision of ubiquitous computing is that of *augmented reality*, in which for example buildings on a campus, or objects in a museum, will be able to 'talk' and offer information about themselves to the pocket computers of passers-by and museum visitors. Such information can be tailored to the native language of the user and reading level or learning style from the information programmed into the handheld device. Dede (2002) suggests a world where: '[The students] wondered what learning was like before augmented reality and ubiquitous computing, when objects and locations were mute and inert. How lifeless the world must have been!'

Less romantic, but compelling as an example of ubiquitous computing, is the now quite common use of palmtops by medical students who need to spend substantial periods away from the university campus gaining practical experience in hospitals and general practice surgeries. Two problems that the palmtops appear to address in this context are:

- the need for students to consult reference information (on diseases, drugs, etc) – bulky, printed books can be replaced by e-books stored on the palmtop (Sommers *et al.* 2001)

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- the need for students to record their experiences, both to report back information to their tutors (to be assessed about their performance in practice) and to encourage students to be *reflective* about their learning experiences (Alderson and Oswald 1999; Sommers *et al.* 2001). It also appears to encourage the students to work collaboratively in a clinical environment taking notes (Ubaydli and Dean 2001).

In a similar vein, some articles report on the use of palmtops for note-taking in the classroom – for example on teachers' use of palmtops to make real-time assessment notes about students (Matthew 1997), and other uses such as tracking class schedules, looking up telephone numbers and reading news-clips offline (Loh 2001).

2.1.3 Palmtops offer access to information and promote the development of *information literacy*

This aspect is common to the use of all computers in educational settings. However, it is argued that this feature can be particularly important when a student has personal ownership of a (palmtop) computer, which can be used anywhere and any time. Pownell and Bailey (2000) describe the concept of 'information literacy as an information-age problem-solving process resulting in [the] productive use of information', which they consider to be at the heart of lifelong learning. Furthermore, referring to the work of Bailey and Lumley (1999), they state: 'In the coming century, the ability to identify, access, apply and create information will be the equivalent of literacy.'

This concept seems relevant to research focusing on basic skills, as it puts the basic notion of literacy (reading and writing) into the context of using IT/ICT tools for 'real life' or 'real world' purposes.

Electronic books (e-books) are a much-discussed issue in palmtop computing (Harrison 2000; Poftak 2001) as a form of information access – see also Section 2.9. An e-book is an electronic version of the content of a book, which can be viewed using a specialised e-book reader device, or on a palmtop using (usually free) reader software. Electronic books have great educational potential but their take-up and availability remain slow.

2.1.4 Palmtops offer the possibility of *collaborative learning*

Inkpen (1999) considers that a weakness of desktop technology is that it has limited ability to support simultaneous interactions between many people. She cites several programmes which have been initiated to give pupils better access to computers through the use of portable computers. The results of some of these studies are mixed, for example the Pupils' Learning and Access to Information Technology (PLAIT) study (Gardner *et al.* 1994) found different results depending on the groups of learners involved and use across the subject area of the curriculum. Other studies involving laptop computers, for example the Microsoft® Anywhere Anytime Learning scheme, have shown that such experience offers the possibility of the students producing a better quality of written work. It also promotes better thinking skills and problem-solving in learners, and more collaboration between students with the laptops

supporting group working and online communication outside school, and teachers acting more as facilitators than lecturers. Inkpen maintains that learning is most successful when collaboration is used, and that handhelds, in the adult model, are individualistic machines (personal organisers).

Gay *et al.* (2002) support this view in their categorisation of the objectives which motivate the use of mobile computers in education. They place communication and collaboration at the highest level of use (see Figure 1).

Figure 1 Levels of objectives: mobile computers in education

Level 1	*Level 2*	*Level 3*	*Level 4*
Productivity	Flexible physical access	Capturing and integrating data	Communication and collaboration
Sample applications			
• Calendars • Schedule • Contact • Grading	• Local database • Interactive prompting • Just-in-time instruction	• Network database • Data collection • Data synthesis • Mobile library	• Real-time chat • Annotations • Data sharing • Wireless e-mail
Content-intensive Users: Individual Mostly asynchronous Information storage Hardware-centred Isolation			Communication-intensive Users: Group Mostly synchronous Knowledge construction Network-centred Interconnection

Gay *et al.* 2002

The simplest applications in Figure 1 provide tools to achieve the objectives of level one productivity, and the most complex applications provide tools to achieve multiple objectives so that an application that enables collaborative work will also enable the collecting and analysing of data. Thus it would seem that the features offered by the use of palmtop computers for the collaborative learning process would also offer the most opportunity for level four objectives.

Palmtops already offer wireless communication in the form of infra-red beaming between two palmtops, or between a palmtop and an accessory device (such as a printer). Radio-based wireless (eg Bluetooth™) is now available on some palmtops. One trial of this technology at school level by Pfeifer and Robb (2001) notes the extended possibilities for collaboration using portable keyboards. Infra-red beaming can also be used by students to exchange concept maps for peer critique. Concept mapping is a graphical technique for representing interrelated ideas, similar to flowcharts, where students can demonstrate understanding of a topic, eg the weather in the MaLTS project using the PiCoMap program (Luchini *et al.* 2002). However, it has been noted that software designers face a challenge in designing support for concept mapping tasks, due to their lack of understanding about how to build in scaffolding to help the students' learning in relation to the content and process underlying the use of palm-sized tools (Soloway *et al.* 2001).

Another benefit is the ability for palmtops with limited memory capacity to use wireless technology to access large information sources on local web servers (Ray and McFadden 2001). However, not all schools or further education (FE) colleges have invested in this technology at present.

2.1.5 Palmtops offer the possibility of *independent learning*

A handheld computer can be considered a true personal computer in that it can provide a sense of ownership, where other computers have to be shared (Pownell and Bailey 2001). Thus, people who prefer to learn on their own, for whom collaboration is not an option or a desire, can be helped by the use of handheld devices. In terms of the objectives outlined above by Gay *et al.* (2002), this would be at level one of the objectives for mobile computing in education.

2.2 Young adults' experiences of using palmtops for learning

There have been very few studies that have included young adults' experiences of using palmtop computers for learning. One exception is the study by Fung *et al.* (1998), which recorded the attitudes of pupils aged 15–16 before and after their use of palmtops for the preparation of Records of Achievements (records which note pupils' achievements and help prospective employers gain a more complete picture of the individual). Small increases were noted in their attitudes to ease of use and usefulness, and decreases in the perception that they are hard to use. The pupils were offered the opportunity to comment on the advantages of pocketbook computing, which were summarised as:

- provided a motivational stimulus
- offered ease of storage and portability
- contributed to improved written work
- made it easier to produce written work
- increased knowledge of computers
- readily available at all times
- offered a range of useful functions.

In a study conducted for Palm™ by Crawford *et al.* (2002), some student opinion was sought from 170 Grade 7–12 students (aged approximately 12–17) about their use of handheld computers. Although students were not asked about the impact of using handheld computers on their learning, it was reported that 88% agreed or strongly agreed that 'using a Palm made learning more fun', and in a free response section 64% noted that game playing was their favourite activity.

However, Alford and Ruocco (2001) note in their pilot study with military academy cadets taking a computer science course, that 'there is little middle ground. Students either totally embrace the use of PDAs, or they ignore them entirely'.

2.3 Game playing and learning

Palmtop computers have a resemblance to handheld game machines like Gameboys™, and it is perhaps partly because of this that students in school trials quickly develop a working relationship with them (Graham 1997). Where students have personal use of a palmtop outside school they are also likely to install games on it, downloaded from the internet or beamed from friends (gaming was also found to be important in Crawford *et al.* 2002). Some people may regard this as undesirable, but is there an educational role for games?

Rodríguez *et al.* (2001) point out the importance of play for learning, as shown by numerous educational psychology studies. Play is a primary learning activity for young children and it remains important for older learners in that it gives the opportunity to rehearse new activities and reflect on ideas without the pressure that frequently accompanies more formal learning. Rodríguez *et al.* have designed collaborative learning games using palmtops (based on previous experience working with Gameboys™) for 7-year-old pupils in the areas of mathematics (eg geometry, identification of mathematical symbols, etc) and the Spanish language. High levels of pupil motivation, attention and concentration were reported. When used at a different school, these games helped the attendance of pupils who had social problems and were involved with drugs.

Horton and Wiegert (2002) have designed a billiards game for a palmtop computer, a traditional game often played by adolescents, to teach geometry to secondary school age pupils. The students need to set up the table and balls and play the game (five turns per player), after which the authors suggested the students write a short paper or conduct a presentation. (Unfortunately no further research details are provided, but more information about Carom billiards can be found at www.thebilliardstour.com/carom.html)

Prensky (2001) considers that handheld computers are an important platform for digital game-based learning, eg for language learning and the management of medical conditions.

As noted earlier, the possible links between game playing and learning are not detailed further in this report, as they will be covered in a separate LSDA publication.

2.4 Palmtops and literacy skills

A number of projects on handheld technology in the UK have investigated the development of literacy skills. These started in the mid-1990s with several trials of the Acorn Pocketbook handheld computer (an educational adaptation of the now-discontinued Psion machines) working with secondary students. Further research has followed (Robertson *et al.* 1997; Fung *et al.* 1998; Hennessy 1998), and has been extended to primary-age students (McTaggart 1997; Pyke 1997; TTA 2001; O'Grady 2003).

School trials with palmtops generally suggest strong benefits for the written work of students, such as the speed with which students can enter text, enhanced presentation, and use of the spellchecker to correct elementary mistakes. In one Australian study (Schibeci and Kissane 1995) although such benefits were found, there was little change in students' writing expertise over the project but on the other hand there was no evidence of an overall decline in writing that some people feared to be a consequence of such use (this study involved Year 5 pupils).

Palmtops can be motivational simply because of their novelty value. For example, according to a primary school teacher, quoted in O'Grady (2003): 'Boys are now much less reluctant to engage in reading and writing activities. Using handhelds motivates and engages them. It doesn't seem to deter girls either.'

They have also been found to assist the writing process of high-achieving students, when written material created on a palmtop computer is compared with handwritten texts (Callan 1994). In this study the opinions of the 14-year-old students relating to the advantages of using handheld computers if they were extended to use by every student were reported as follows:

- better organised notes
- less paper used by schools
- all work is typed and therefore neater, easier to read for student and teacher
- would teach generic computer skills, including programming
- data is entered in a universal language that can be transferred to any other computer without recopying
- improved essay writing with spell-check and grammar-check features easily used on imported text
- offers the same advantages as a full computer only in a more portable device
- takes the power of a computer anywhere
- homework can be completed on a school bus converting travel time to work time
- gives a professional look to all the student's work.

The word-processing tools of palmtops provide assistance to students through the use of wireless technology. Here enhanced effects can be claimed where students work collaboratively, beaming documents to each other to share and criticise each other's writing. This is claimed to support the learning cycles of doing and reflecting by encouraging students to revisit written work frequently and to share and comment on each others' drafts as a reflective discourse which increases the quality of the finished product (Soloway *et al.* 2001; Becta 2003; Perry 2003).

A useful reference is the website of the National Literacy Association, who are undertaking some work with palmtop computers, at www.nla.org.uk

2.5 Palmtops and numeracy skills

The earliest electronic handheld device for assisting with numeracy was the calculator. A review of the use of the calculator to assist learning is not included here and a brief search of the literature yielded no studies specifically related to the area of learning basic skills in mathematics.

One study using palmtop computers in relation to students' graphing skills is notable because it reports the benefits that students rated as important when using portable technology (Hennessy 2000). This study was conducted with students who had some knowledge of spreadsheets and graphing, and included some disaffected students, as well as some with special needs and learning difficulties. They used palmtops to collect weather temperature data over time. The students' ratings of portable technologies were combined into the following themes (so although this is one of the few studies which gives student views, it is indirect feedback):

- flexibility and use outside the classroom
- personal ownership
- prefer typing to handwriting
- no domination of machines
- independent working
- greater computer access
- more interesting than desktop machine
- makes maths more interesting.

Positive gains were also reported in their motivation and improved attitudes to the use of new technology.

2.6 Palmtops and social issues

It has earlier been noted (see Section 2.3) that a handheld computer game developed by Rodríguez *et al.* (2001) and used with young pupils, aged 6–7, helped their motivation; the pupils displayed high levels of attention and concentration. In a different study involving 12 year olds, many of whom were involved with drugs and had other social problems, their use was found to influence the pupils' voluntary attendance. Elsewhere, they have also been found to help teacher–parent communication (Strom and Strom 2002). In this study, teachers in one high school used PDAs to record students' conduct. They sent signals to pagers to contact parents quickly to correct inappropriate behaviour or reinforce good behaviour. The PDAs facilitated the keeping of accurate records and paging was an efficient way of contacting parents. The study also reported improved learning conditions for the students in relation to their awareness, peer relationships, amount of time spent on-task and self-regulation.

2.7 Palmtops and special needs

There have been a number of initiatives to use palmtop computers with people who have a variety of special needs. Examples of these follow:

- deafness, where a third-generation mobile device (called WISDOM) for deaf people has been designed to visually recognise continuous sign language sentences in the German language, allowing person-to-person live communication over distance in sign language in 3D (Bauer and Kraiss date unknown)
- cognitive impairments, using a prompting system (called MAPS) to assist in shopping and bus trips (Carmien 2002)
- as an adjunct to cognitive-behaviour therapy for panic disorders, where a person uses a palmtop computer if they are having a panic attack (a series of questions appears on screen to slow down their breathing and help them reflect on their fears) (Newman *et al.* 1996)
- severe developmental disabilities, eg where schedule-prompting software as a visual assistant, and audio support on a palmtop PC, help people perform their vocational and daily living tasks with increased accuracy in completing tasks (such as being requested to begin labelling a floppy disk, taking a break, and then resuming the activity). This was noted as helping their independence and self-confidence (Davies *et al.* 2002a, 2002b). A similar program called VICAID is a palmtop-based job aid for workers with such difficulties which can be used for task scheduling, for example to assemble a valve in 26 stages, which can also be useful for those with attentional difficulties (Furniss *et al.* 2001)
- motor impairments such as muscular dystrophy where movement is difficult and the handheld function of word prediction is useful (Myers 2000).

The ability to convert text-to-speech and speech-to-text is not specifically a technology for use by people with special needs, rather one which can be used by many people. This is a developing field for palmtop computers including the following examples.

- There is a program in India using a handheld computer called a 'Simputer' which reads aloud web pages written in English and converts them into three Indian languages — Hindi, Kannada and Tamil (Singh 2002). This project was designed to connect people living in rural villages to the internet through the telephone kiosks that are ubiquitous even in the countryside. A pilot study has now begun to broadcast adult education and basic literacy packages by satellite for downloading to central locations accessible by the Simputer.
- Prototype systems have also been developed for learning Mandarin (Kumagai 2002), Kanji (Fukuda *et al.* 1995) and the pronunciation of Indonesian (Nelson 1998).

2.8 Educational software for palmtops

A problem noted by several articles is the general lack of good educational software for palmtops. According to Loh (2001), the educational 'killer app' (a software industry phrase for the 'must have' piece of software which convinces people to invest in a certain type of technology) for palmtops has not yet emerged. Thus, educators are unsure of the technology and although palmtops are relatively cheap, compared with laptops, the trade-off of reduced functionality can be a deterrent.

Soloway (2001) writes in terms of the 'cool half-dozen' educational applications which are required to make palmtop computers routinely useful in the classroom and thus justify the cost of one per student (he suggests three candidates – one of which, *Cooties*, is reviewed in Section 3.1). Perry (2003) describes recent experience of palmtops in UK schools, where students are full of enthusiasm for the machines but teachers feel rather uncertain. He suggests this is not only because of their novelty, but also because of a lack of clarity about useful educational software applications.

> *The identification and implementation of existing applications and the development of new ones will need to be led by technically competent people in collaboration with teachers. Information on current applications should be made available to all user institutions in conjunction with advice and support to get the most out of software for educational purposes ... Many would say that the conclusion that learning applications are limited is premature and that the lack of this use is more the result of the limitations of the time so far given, teachers' skill development, and teachers' confidence and awareness of available applications, not to mention teachers' limits in being able to develop applications themselves. However, as shown by many examples in the USA in particular, there are an enormous number of small, classroom specific applications available. But it takes a great deal of time and experimentation to find and evaluate them (eg see websites such as www.palmgear.com/software). Many would also require 'localisation' to make them useful in English schools.*
>
> Perry 2003, pages 13 and 16

Nonetheless, palmtop machines do have standard built-in applications that are very useful across all learning activities: ie the word-processor, spreadsheet and graphics/drawing programs. These, combined with the infra-red beaming facility, can produce some impressive results in educational settings (see Section 3).

2.9 Electronic books (e-books)

Electronic books (e-books) are digitised versions of books that can be read on a desktop or laptop computer, handheld device, or with a dedicated e-book reader. They have been enthusiastically recommended as educational tools for some time, but have so far failed to make a significant impression on consumers or in schools. The reader devices have suffered in the past from being bulky to carry and having low-contrast screens which are not ideal for

reading (Poftak 2001). However, the screens have developed further in the last few years, for example colour screens are now available. Electronic books could offer more cost-effective access to text materials, because they avoid the problems of educational institutions investing in large numbers of printed books which become outmoded, and without the waiting times involved for new print-runs to correct outdated information. They also offer the possibility of an 'interactive' experience with content.

In a study by Simon (2002), 10 pocket e-books were used in a biology course to replace textbooks. It was found that the students read their e-books in more locations, but that the amount of time spent reading did not correspondingly increase. In comparisons, those who preferred e-books mentioned the backlight facility and the ease of bookmarking specific information, and those who preferred textbooks stated it was easier to turn the page of a book than to scroll and that e-book images were poor. According to the students the main advantage of the e-book was its size, weight and portability, compared with a course requiring a number of different science texts.

One issue with e-books is whether to use a general palmtop or a specialised reader. Although the specialised devices are more expensive for what they do, they have good features for reading, such as larger screens than typical palmtops, and some models are particularly intended for younger readers (with 'child friendly' built-in dictionaries, spell checkers, large buttons, and so on – see for example the machines made by Franklin Electronic Publishers at www.franklin.com/). They are also being used with pupils who have difficulty reading text because of a learning disability – for these learners electronic text is combined with a talking word processor (Poftak 2001). As with palmtop computers in general, the technology is immature, and there is still no standard e-book format (Harrison 2000), although the Open eBook Forum (see www.openebook.org/) is working towards this.

Harrison (2000) maintains that the future is promising for e-books, but the key to their success is whether users have motivation to buy one and use it. This will come with compelling content and how it feels to read that material on the e-book when compared to an ordinary book.

2.10 The ownership of technology: benefits and pitfalls

As already indicated, the benefits for a student of 'ownership' of a palmtop, even as a temporary loan, are generally very positive:

> *I love my PDA. I can't ever imagine lugging a laptop computer around with me, but I take this everywhere I go. When I baby-sit I do all my homework using my keyboard and the word processor, and I don't waste any time transcribing things later. I get so much more done in less time now.*
>
> US high school student, quoted in Pfeifer and Robb 2001

[G]iving children a PDA lights up their enthusiasm, though whether this will always be the case, whether they might tire of them in time, or whether PDAs will eventually become 'yesterday's news', remains to be seen. In the meantime, there is potential here to be exploited by, for example, targeting disaffected boys.

Perry 2003

Personal ownership poses a challenge to the institutional control of technology. If students are provided with computing devices for personal use, they will want to use them for other things at home (eg using personal computers for online chatting, games-playing, web-surfing for music). To some people, such activities might not be considered educational. Cook (2002) reports on one project that offered personal laptop computers to all its 11,500 12–14-year-old students. A number of cases of abuse (50–60 students accessing internet pornography at home; two students hacking into teachers' computers) led to an institutional policy of regularly 'scrubbing' (wiping clean) all the computers' hard disks. But this can also be seen as preventing the students using the computers for the things they enjoy most, eg instant messaging and downloading music. One student complained 'I think they should be able to restrict it at school, but when we're at home it's a different environment, we should be able to do what we want to do.' It was reported by the superintendent that the one thing they would have done differently would have been to make the laptops more secure. It seems that any project involving personal technology must set out a 'fair use' policy which balances the freedoms and responsibilities of students; especially projects which operate outside the everyday situations within institutional walls.

2.11 Problems with palmtop computers

This literature review presents a generally positive picture of palmtops in education. However, some problems are also reported. Perhaps the greatest problem is that palmtops are a young, rapidly evolving technology and there are several incompatible technology platforms competing in the marketplace. Many research trials of palmtops in education are funded by government, or public research programmes, and are often subsidised by palmtop manufacturers themselves, so they are somewhat insulated from realistic buying decisions.

A number of articles warn about the physical fragility of palmtops in the rough environment of schools and the likelihood of theft (Jackson 2002; Perry 2003), but reports from actual trials suggest that these are not significant problems in practice. Perry (2003) notes two contrasting policies used by different schools in a current UK trial – one heavily underlines to the pupils their responsibility to avoid damage or loss, while the other reassures the pupils that they will not be penalised for damage or loss because the school's prime concern is to explore the benefits of their use (although all reasonable precautions should be taken).

Palmtops are currently designed primarily with the interests of adult individual users in mind, generally those who are business-oriented. Two issues arise directly from this.

- Palmtops are generally provided with 'hot sync' cradles to communicate with desktop computers (the device is dropped into the cradle and there is an automatic synchronisation of the contents of the palmtop memory with the palmtop folder on the PC). This usually works well for an individual user, but is much less appropriate where a large number of students need to transfer data at the same time.
- The second issue is the lack of good educational software for palmtops, which is subject to a 'Catch-22' effect (schools will not invest in palmtop technology until good educational software is available, software companies cannot find a market for educational software until schools invest in palmtops), but as the education market slowly grows, software is becoming more available (see more in Section 3).

Other general pitfalls with using palmtops in the classroom include practical tasks such as printing – ie where all 30 pupils are trying to beam documents to a printer at once (Shields and Poftak 2002). The importance of keeping batteries re-charged is also important, otherwise work could be lost (Perry 2003). In another study, after 2 months of using palmtops in their residency medical students found it difficult to carry cumbersome modem cords, use incompatible platforms (noted above), get internet access at times because of the limited capabilities of the browser, find analogue telephone lines and synchronise with home computers (Beasley 2002).

3 EXAMPLES OF USING PALMTOPS FOR LEARNING

3.1 The Cooties game

Many projects have found that beaming between palmtops has a direct effect on learning, especially for collaborative working and group working, and increases in the amount of writing produced (eg students can beam their writing to a friend, get feedback and revise) (Shields and Poftak 2002). An interesting use of beaming is a virus simulation game in learning science, Cooties, as described below.

> *Traditionally, exploring the spread of communicable diseases calls for students to drop chemicals into water-filled beakers to determine the presence or absence of 'sickness' in each beaker. However, new software for the Palm developed by the University of Michigan offers a more dramatic way for kids to understand the biological and social implications of disease.*
>
> *Developed with middle school students in mind, the Cooties program simulates the spread of disease through the 'infection' of students' handheld computers. First, students create a personalized 'coodle' on their Palm device (the idea is that just as they wouldn't want a pet to get sick, they wouldn't want their coodle to either). Meanwhile, the teacher secretly 'infects' one student device with a 'disease', and the remaining with varying degrees of 'immunity'. Next, students mingle together and start beaming each other, sometimes with consent and sometimes not. As the simulation progresses, the coodles get sick, and when that happens, the infected student sits down. The game proceeds in rounds, with the disease carrier reset each time. Using scientific processes, students then develop hypotheses about the spread of the disease.*
>
> *For Alycia Meriweather, who teaches at the Farwell Middle School in Detroit, Michigan (USA), the Cooties unit works for several reasons. It capitalizes on the gregarious nature of middle schoolers. It teaches subtle concepts in a fun, engaging way that models true scientific thought. It also provides a powerful venue to discuss real-life issues. 'This gives us a safe way to discuss sexually transmitted diseases and the importance of knowing the history of who you interact with,' says Meriweather.*
>
> Shields and Poftak 2002

This is reported by Shields and Poftak (2002) to fit well with the constructivist models of teaching and learning, which encourage students to be inquisitive. However beaming is also controversial, eg one school in the study complained that a student downloaded an application that let him use the handheld computer as a television remote control unit in class, and that students play games and send personal e-mails in class time.

(More information about the Cooties game can be found at www.goknow.com/Products/Cooties.html)

3.2 Geney™

Geney™ runs on Palm PDAs and is a collaborative problem-solving application to help children explore genetic concepts. It was developed through a user-centred, iterative design process on the basis that as computing devices become smaller, the technology becomes more individual and so the opportunities for interpersonal communication become problematic. The Geney researchers want to find out how collaborative learning activities can be structured using handheld computers so that support of learning activities related to genetic concepts and problem-solving becomes the goal (rather than the use of the technology itself). The following research questions were studied.

- How can handhelds be adapted for use by children (as they are primarily understood and designed for adults)?
- How can handhelds be used for collaborative activities?

> *Geney™ simulates a population of fish representing a gene pool. The fish are distributed across multiple Palm devices, each Palm being a single pond of fish. Fish mature, get older and eventually die. Students can exchange fish with their friends through the Palm device's infrared port, and they can arrange to mate fish within the same pond. These fish eventually have offspring that have genetic traits derived from their parents' genes … The goal of the game is for students to collaboratively work together to produce a fish with a particular set of characteristics. This set of characteristics will be specified at the time the gene pool is distributed to the Palm devices at the start of the game. At any time, students have in their Palm devices a limited picture of the entire gene pool and of the family trees for the fish in their pond. Only by working cooperatively with other students playing the game can the class achieve the desired goal.*
>
> Danesh *et al.* 2001

The researchers conducted a very comprehensive development process: requirements analysis using paper mock-up designs and scenarios; validating requirements with target users; prototype development; prototype testing with target users; and the development of a complete application specification. The validation phase was particularly important, because palmtops are adult-oriented devices and the researchers had to establish the particular ways in which children interacted with them, including how they used the built-in software applications of the Palm device. (See Section 4.2.2 for the findings of this research on interface design.)

The most striking observation about children using Geney™, based on informal evaluation, is the richness of social interactions that it produces. Even children who were less inclined to work with others were included. The authors plan further research to formalise the evaluations and to research the

pedagogical aspects of the collaborative activity. This environment has also been found to excite and motivate learners to interact (Mandryk *et al.* 2001).

(More information about the Geney™ game can be found at http://geney.juxta.com/game.cfm)

3.3 The Docklands Learning Acceleration Project

The Docklands Learning Acceleration Project, run by the National Literacy Association, distributed Acorn Pocket Book computers to 15 schools (35 computers each) in the inner London boroughs of Newham, Tower Hamlets and Southwark; in total 600 7-year-old pupils were involved (McTaggart 1997; Pyke 1997).

The aim was simply to increase the amount of children's reading and writing. The project reported excellent results, but unfortunately the available articles provide only a few glimpses of what was achieved. For example:

> *My less able children begin by taking the text of familiar story books and using the edit facilities to change characters, adjectives and events ... this provided scaffolding. The children didn't have to create stories out of thin air. It has helped them to see how stories are constructed.*
>
> McTaggart 1997

> *[After a year] I can see an improvement in the children's literacy skills. Because they can use the spell-check and the thesaurus, it leaves me free to work on the content of their work.*
>
> McTaggart 1997

It is reported that students 'borrow more complicated and quite "wordy" books now' (school librarian) when compared with the previous school year. In a formal research study of the trial, it was found that the schools improved from having a persistent record of below-average reading achievement (8 months reading age per 12 months of time), to 11.5 months per 12 months, after one year of using the palmtops (Pyke 1997).

A later trial in a primary school (TTA 2001), based on the Docklands project, noted similar findings in terms of children's' motivation to read and write:

> *increased motivation to write, revise and redraft amongst the children, and ... involvement of parents and carers. Because the palmtops were taken home, parents and carers became involved in the written work to extend the child's ability to use written language, thereby raising awareness of literacy issues in children's lives and increasing informal contact between home and school. ... [T]he teacher also noticed gains in the quality of the writing the children produced. He believed the printouts and publication of the children's writing added to the quality by emphasising the communicative nature of writing to the children. This developed their sense of audience and the purpose for which the writing was to be used.*

This was supported by the results of formal testing for reading comprehension. This study did note that:

> *Palmtops are more useful at certain stages in the writing process than at others. They appear to facilitate revising, redrafting and editing, but do not appear to help in the composing and reviewing stages of the writing process. It would seem that the planning and initial drafting of a piece of work are best done by hand, at least until pupils are competent in keyboard skills.*
>
> TTA 2001

It also noted that because of the smallness of the palmtop display 'it was difficult to see the overall shape of the evolving text, to locate information or detect errors on the screen', so the children preferred to revise text on hard copy.

Further references can be found listed in the report by Becta (2003) and also ongoing projects by the National Literacy Association (www.nla.org.uk/).

3.4 Science fieldwork

> *When a New Jersey student joined her class in a walk through the woods, she later told her teacher that she enjoyed her experience. Yet when the teacher asked, 'What in particular did you notice?' the student answered, 'Lots of details.' She could not, however, remember any of those details. This student's experience was not unusual. Our finer-grained observations tend to slip away unless there is some way of focusing our attention more sharply and recording details immediately so that we can more easily revisit them*
>
> Tinker *et al.* 2002

Trials of palmtop computers in schools indicate that they have a natural home in science fieldwork, where their compact size gives them an obvious advantage over other type of computers. Their built-in spreadsheet software is powerful enough for on-the-spot data analysis, and the word-processing software allows note-taking and report-writing. It is possible to connect the palmtop to various sensor devices (temperature, air pressure, motion detector, etc) for electronic data collection known as data logging. Another use, especially relevant to biology fieldwork, is to load up the palmtop in advance with information about the plants and animals that might be encountered during the fieldwork.

Graham (1997) describes a project involving primary schools in Birmingham and the city's botanic garden, where the students used palmtops to:

- prepare for a visit to the garden (creating databases of technical terms and botanical information)

- conduct observations and environmental measurements during the visit
- analyse the collected data and write up a report after the visit.

It was found that the use of palmtop computers helped raise the performance of pupils with low attainment by supporting literacy as they allowed individuals to focus on the task rather than be distracted by perceived handwriting and spelling inaccuracies. (For more information on this project, and others, visit the DEPICT Project website:
www.bgfl.org/bgfl/activities/intranet/teacher/ict/depict_project)

Gay *et al.* (2002) report on a pilot study of four palmtop computer applications for undergraduate students in botanic gardens. This research is based on the use of Activity Theory, often found in the field of human–computer interaction, which focuses attention on action, doing and practice, but within the 'activity' as the unit and content of analysis. Each of the applications has been evaluated separately. Although interest and enthusiasm were noted throughout, a handful of student experiences were also directly reported – where, for example, some concern was expressed at the possibility of the technology spoiling the feel of wandering in the gardens, that the paper sheets used were just as good as those designed for the palmtop, completing the electronic exercises 'made it easy not to think for yourself' and 'if anything, more hands-on [work] such as writing and act of counting would be conducive to learning'. Gay *et al.* state the importance of considering how technology meets users' needs and how it affects the process of learning (their categorisation of the objectives which motivate the use of mobile computers has been reported in Section 2.1.4). Further work by these researchers is described at www.hci.cornell.edu/

3.5 Palmtops in physical and sports education

According to Juniu (2002), the most important benefit for educators and students is the PDA's ability to extend the learning environment beyond the classroom. As with science fieldwork, palmtop computers have benefits in physical and sports education. For teachers, students' performance can be recorded, analysed and graded directly with the palmtop; also a palmtop plus digital projector can be used to give presentations 'in the field'. Students can use the palmtop to record and analyse their own physical performance; and beam their reports to their tutor. Brown (2001) reports on this kind of use by secondary school students and Mohnsen and Schiemer (1997) report on creating learner profiles for physical educators.

The paper by Juniu (2002) gives an overview of palmtop hardware and software applications relevant to physical education in 2002 for the PalmOS® and Microsoft® Windows CE palmtops. Uses include grading and attendance, assessment portfolios, fitness and wellness assessment, lesson planning organisation, and quiz-writing used in a gymnasium or outside. There are also generic palmtop applications: word-processing, spreadsheet, database, e-books and web browsing.

3.6 Reflective logs

An interesting finding that has emerged from trials of palmtops with medical students and student teachers is the effect on learning that can result from the use of palmtops for 'reflective logging', ie using the palmtop to record students' observations in the professional situation they are working in. These observations can be fed back to tutors for formal assessment of learning but they also form an important source of data for the students themselves to reflect on their learning. This seems to be particularly effective because the palmtop is compact enough to be always with the user and can be used anywhere.

Crippen and Brooks (2000) describe a trial in which supervisors of student teachers used palmtops for observing the students in the classroom. This allows immediate follow-up discussion with the student, as the supervisor can e-mail the observations to the student as soon as they return to their desktop computer or, if the student also has a PDA, the report can be beamed directly to them. Compared with the pre-internet situation, interactions between students and supervisors became 5–10 times more frequent. Keeping a journal was found to help the student teachers reflect on their teaching experiences and it also increased their rapport with the tutors and their computer proficiency. The particular palmtop machine used (PalmPilot) has some useful technical features for recording as data entry is very quick. It is also possible to set up shortcuts ('typing macros'), for example writing 't s' inserts a 'time stamp' into the observation record.

The literature reviewed does not consider reflective logging in any detail. Teenagers' enthusiasm for text-messaging via mobile phones suggests that they might be willing to use a palmtop to keep some kind of reflective 'diary'. This may be similar to the popular internet phenomenon of 'blogging' (the publication on a website of personal thoughts and opinions). A recent paper by Lester (2003) looks at what happens with blogging in a community of users of a wireless networked handheld device (a type of 'smart phone'):

> *[I]t appears that by having ubiquitous mobile data communication devices and a successful communal blog, it is possible to create an ideal environment within which a smart mob can grow into a goal-oriented mobile community of practice. … The increasing popularity of communal blogs, coupled with more sophisticated ubiquitous mobile communication devices … will most likely make this interesting social phenomenon more common in the future. A future opportunity will be the deliberate cultivation of this phenomenon, as it has the ability to create incredibly effective and creative goal-oriented teams of mobile individuals.*
>
> Lester 2003

4 PLANNING AND DESIGN ISSUES RELATED TO LEARNING WITH PALMTOP COMPUTERS

4.1 Selecting palmtop technologies

Palmtop computing devices are evolving rapidly and suffer from the existence of a number of rival and incompatible operating systems (MIT Information Services 2002). The strategy that many institutions adopt is to select one type of machine for everyone involved in the project.

A number of recent reports eg reports produced by Becta, TechLearn and TechDis (Rainger 2002; Perry 2003; Smith 2003) note the different technologies available, which inform the selection of palmtop technologies. The Concord Consortium website is also useful for this (see www.concord.org/research/handhelds.html).

A developing area of interest is the merging of palmtop and mobile phone technologies: 'smart phones' are mobile phones with added palmtop-like functionality, and high-end palmtop machines now work as mobile phones. Smith (2003) suggests that the biggest growth will be in smart phones, since these are being intensively marketed to users by the mobile phone network operators.

A worrying trend for educators is that manufacturers want to produce increasingly powerful palmtop devices, which may be too complex and expensive for student needs. O'Grady (2003) reports on one Welsh primary school which has for some years worked extremely well with Psion machines which have now been discontinued, and is finding that the available alternative machines are all rather more expensive.

There are specialised palmtop devices that may be worth considering for restricted applications. E-book reader machines appear to be much better than general-purpose palmtops for reading e-books, with larger, more readable screens and special designs aimed at younger (or less able) readers, which feature targeted dictionaries and spell-checkers (for example, see www.franklin.com/). Another important specialised device is the graphical calculator. This is similar to an ordinary calculator but can also display graphs and other diagrams, process large amounts of statistical data and carry out pre-programmed sequences of instructions. The use of graphical calculators is reported to have advantages for learning mathematics (see Becta's information sheet at www.t3ireland.ie/t3ireland/Files/graphcalc.pdf). Section 2.5 notes the use of palmtop computers for learning graphing skills and the use of calculators for numeracy.

4.2 The design and development of products

A few of the papers reviewed gave detailed guidelines and examples of the design and development of software applications for palmtops, these are summarised here.

4.2.1 Guidelines for the design of interfaces and presentation of information

According to Hayhoe (2001), the most significant design restrictions of palmtops are the small display screen, and the limited brightness and contrast. His guidelines for dealing with this include the following.

- *Realize that reading online at low resolution reduces reading comprehension significantly*
- *Think in terms of nuggets or specks, not chunks*
- *Be prepared to display text in larger type than you are accustomed to seeing in documents designed to be read on the desktop*
- *Apply bold, italics and colour with caution*
- *Don't expect to have access to a large variety of fonts*
- *Employ graphics in very minor supporting roles rather than as a primary means of communicating information.*
- *Don't assume that other supporting media will be available*
- *Remember that most of the current installed base of handheld and wireless devices have very modest capabilities*
- *When designing for a particular installed base, consider the capabilities of the standard device in design decisions*
- *When designing Web pages for reading on handheld devices, remember that the screen orientation is portrait not landscape, and that the screen width is very narrow*

(An online version of this article can be downloaded from: www.stc.org/49thConf/Session_Materials/file_2a.asp?ID=111)

Online help systems are an important supporting component for educational software. Hayhoe notes some technical problems with this: PalmOS cannot multi-task, and although PocketPC systems can, the interface is not helpful for switching between programs. Thus, Hayhoe's suggestions for help systems, web content and e-books include the following.

- *Consider seriously the need to provide user assistance for all handheld and wireless applications, no matter how simple*
- *Convince programmers to provide a link from the application to the online help*
- *Include a one-page table of contents for at least the first level help topics*
- *Ensure that help is task-based, succinct and sufficient for various user types*
- *Organize help topics using a streamlined step model*
- *Offer HTML, HDML and WML versions of web content*

- *Provide suitable navigation, writing, content depth, information display and supporting media for each version*
- *Use each platform's de facto standard format to deliver e-book content to handheld devices*
- *Use the appropriate platforms to write and test documents*
- *Never ship a document without testing it with real users*

Finally, Hayhoe notes that user environments for handhelds are very diverse, and makes the following suggestions for designers relating to users' environments and the tasks the users perform.

- *Always analyze users, their tasks and their environments when designing online documents for wireless and handheld platforms*
- *When applying the results of your analysis to the design, be sensitive to the wide range of places, times, atmospheric conditions, lighting and noise levels in which your electronic documents will be used*
- *Minimize file sizes to ensure quick loading of documents and to reduce the space required to store the document and load it in working memory*
- *Limit the amount of interactivity and scrolling required to avoid user annoyance and frustration*
- *Recognize that these devices are almost always held in one hand, so the user has only one hand free for interaction with the device*
- *Be aware of a variety of user postures*
- *Limit the use of sound, and allow the user to mute it easily*

4.2.2 Design issues for handheld computers in learning

According to Inkpen (1999), the design of handheld technology for children must not follow models used for adults; child-centred research is necessary to determine the right models. The research described in this paper focuses on two aspects of the use of handheld technology in learning environments – mobility and shareability ('the capacity for children to interact collaboratively while using the technology'). Handheld computers, in the adult model, are individualistic machines (personal organisers) – but learners are most successful where there is strong collaboration.

Inkpen (1999) carried out an experiment with 10–12-year-old children, focusing on participatory design sessions to create low-tech prototypes representing their views of how handheld technology should be. One interesting point was the identification of a need for a compact printer to go with the computer, also voice recognition for input and output. Another activity was to give children an 'imaginary computer' (a coil-bound notebook) and ask them to imagine it was a handheld computer, carry it around for several days and record where they would like to use it, and what activities they would like to use it for. It was notable that children's 'what' suggestions (ie what they would like to be able to do with a handheld computer, eg use it for games or music) had strong collaborative characteristics. However, their design prototypes were weak in this area, suggesting their design thinking was constrained by existing technology.

Danesh *et al.* (2001) and Mandryk *et al.* (2001) are concerned about the problem of promoting collaboration, investigated around the development of a palmtop-based educational game, Geney™ (see Section 3.2 for description). Danish *et al.* (2001) note the following design guidelines for palmtop applications for children (specifically with PalmOS machines).

> *Menus: The Palm environment uses a menu model in which menus are not always visible on the screen in order to save space on the small display … Children had difficulty remembering the action to bring up the menu and commented that they would prefer the menu to be visible on the screen as with traditional desktop interfaces.*
>
> *Beaming: All students were able to understand and utilize beaming in the Palm environment, however some had difficulty executing the process. The children found it easier when scaffolding mechanisms were provided to demonstrate how the beaming process should unfold (eg prompt the children to point their Palm at the other Palm).*
>
> *Graffiti®: Given that Palm devices lack a keyboard, a stylus is required for all data entry. Two methods are available for text entry: tapping on letters on a pop-up, on-screen keyboard image, or using Graffiti, a specialized handwriting recognition system which uses simplified letter forms to achieve high levels of accuracy. Children were able to easily use both methods of text entry. In terms of preference, students expressed a strong liking for writing with Graffiti. This preference seemed to be based on the novelty of Graffiti and the fact that the on-screen keyboard obscured information on the screen.*
>
> *Scrolling: Because of the limited screen space on Palm devices, applications that handle large amounts of data inevitably resort to scrolling as a mechanism for accessing information that doesn't all fit on the screen at one time. The children were able to utilize scrolling effectively. It appeared to be important to present as much information as possible at each level and avoid deep structures of embedded screens and dialog boxes.*
>
> *Consistency: Consistency can be viewed from several perspectives for handheld applications. First, consistency within an application; second, consistency across Palm applications; and third, consistency with other computer applications. Even with the limited exposure that children had to Palm applications, they easily noted inconsistencies between applications and expressed frustration about this (eg in some applications the menu was visible while in others the menu was hidden until the menu-button was pressed). It is important to ensure consistency internally within an application, externally with conventions of Palm application design, and globally outside of handheld interfaces.*
>
> *Feedback: As in most interface design, feedback is an important issue. Throughout our experiences, we observed prompts for user action that were easily missed by the children (eg during the beaming process). In*

addition, children also commented on the need for descriptive menu entries. Consideration needs to be given to clearly indicate prompts for action as well as feedback on actions taken.

Undo Facility: The need to provide robust and pervasive canceling and undo facilities was clear. In many instances errors or inadvertent actions were committed, and it is important that children be provided with the ability to cancel all steps if necessary.

Customization and Creativity: Many of the children indicated that they would like to be able to choose the type of animals [in the software developed by these researchers]. The ability to customise and express their creativity was important to the children. This is common for children's interactions in general and has been commented on in previous research on children's technology

Danesh *et al.* 2001

The design guidelines suggested by Jipping and Dieter (2001) are interesting for their degree of 'learner centeredness' in the CARDS (Classroom Application Rapid Deployment System) project, ie putting the learner at the centre of his/her learning.

- *Students need to take ownership of their computing environment. The student, not the computer, needs to be the center of a computing environment. This implies that the student needs to be as comfortable and confident of the computer as she is with a notebook or pencil. This involves psychological issues (eg human-computer interfaces) and physical issues (eg mobility and computer size).*
- *Information needs to seek out the student, not vice versa. If the student is to be the center of the computing environment, we need to make the student the target of information. We need to bring information to students, not the students to the information. This means more than email; it means updated files and Web pages that are sent to a student's computer when it connects to the network. It also means collecting information from students, eg completed responses to the questions posted yesterday, automatically.*
- *The tools used in the computer environment need to naturally extend to a student's computer use. Computing technology often bends a user's usage patterns to fit the technology. If a computer becomes as common a tool as paper and pencil, this 'usage bending' should not be tolerated. Students will adapt to the computer when the new tools are natural extensions of their experience*
- *Computing facilities need to empower a student to be a part of a larger community in natural ways. We must use the technology we have at our disposal to establish community. This means turning from computers in cubicles in a lab setting and turning to students sitting at a conference table sharing data over a wireless connection. This means enabling connections from locations where one would not normally find a computer system*

Jipping and Dieter 2001

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Similar guidelines have been suggested for people who have cognitive disabilities (Carmien 2002), in that the device needs to:

- *[be] easy to carry*
- *display an image of high enough quality to be experienced as a 'picture' rather than an icon*
- *have sound quality and volume enough for clearly hearing prompts in outdoor environments*
- *be robust both as a software platform and as hardware: to minimize focus on the tool and maximize the use of the tool*
- *have affordances 'chunky' enough for not so finely co-ordinated fingers [we interpret the term affordance to be how the design of the palmtop computer influences its interactive relationship with the user]*
- *provide positive feedback of visual or auditory nature to indicate that controls have been activated*

King 1999 quoted in Carmien 2002

4.3 Other approaches to data gathering with palmtops

There are two other notable approaches to data gathering on palmtop computers.

4.3.1 Electronic logging

According to the literature, there are two main types of logging (regular recording of particular kinds of information) with palmtops:

- manual logs allow learners to more easily record their experiences 'in situ' (eg Alderson and Oswald 1999) – this works for the learner's and teacher/organiser's benefit, as well as for a project development team to gather technical feedback
- automatic electronic logs (ie audit trails) can record what or when knowledge or information the learners consult (what is most useful, what is missing, etc) – for the benefit of the organiser/developer (Labkoff *et al.* 1995). Such logs can be useful to researchers for triangulation, providing quantitative information about the use of a palmtop computer (although not necessarily by the individual user).

4.3.2 Student sampling and questionnaires

The report of Ubaydli and Dean (2001) presents one project's experiences relating to a trial with fourth-year medical students at the University of Cambridge using m100 Palm Pilots. Specific software was developed, particularly focusing on the issue of information sharing – eg rewarding students who upload information by greater access to information, and introducing a competitive element to sharing (point scoring, league tables). This report contains notes of the process of student selection for a trial, and getting feedback from students using questionnaires.

A notable feature of this project was the use of screening interviews to target students with some commitment to the aims of the project, ie they needed to be a 'technology enthusiast' but also an enthusiast for the subject matter of the study.

5 CONCLUSIONS

Although they have been available for the past 6 or 7 years, the use of palmtop computers for learning is a relatively new area. Many teachers and students appear not to have adopted them for use in the classroom, or elsewhere, considering the technology to be new and untried when compared with desktop, or even laptop, computers. There are many reasons for this, not least of which is the lack of relevant educational content for palmtop computers, including software applications and learning resources. There are also business-related and technical issues, such as several competing and incompatible operating systems in the marketplace. Thus, there have been few:

- comparative research studies
- studies that relate their work and outcomes to theories of learning
- studies which include reference to, or examine in depth, the views of the participants, particularly the learners, to the handheld technologies they are using.

There also appear to have been no studies in the area that relates directly to the target audience of the m-learning project, which is young adults aged 16–24 who are disengaged from learning and who may have literacy and numeracy needs. The only educational setting in which palmtop computers have developed a reasonable maturity is university medical education, where students gaining experience in hospitals have to be highly mobile and require a computer technology to match. This is expected to change in the future as the technology becomes more accessible due to the closer alignment of the mobile phone and palmtop computer markets. Furthermore, there is much research currently in progress, particularly in the schools and university sectors, which will be reported in the next couple of years.

Specifically relating to the m-learning project, the following topics appear to be important and should be taken into account in research and design activities:

- information literacy (which puts the basic notion of literacy, as reading and writing, into the context of using IT/ICT tools for real-life, problem-solving purposes)
- the design of both collaborative and independent learning activities
- game-playing and learning
- the use of palmtop computers for activities outside the traditional classroom, eg for physical education and sports activities
- reflective logs and blogging
- guidelines for the design of interfaces and the presentation of material on handheld devices.

APPENDIX
METHOD USED FOR FINDING RESEARCH STUDIES ABOUT LEARNING WITH PALMTOP COMPUTERS

The aim of the review was to identify and synthesise the relevant world literature about the use of palmtop computers as one type of mobile technology which could be used for learning. Because of the scope of the m-learning project, the literature base encompassed a number of different areas, including:

- use of IT and ICT
- acquisition of basic skills (including literacy and numeracy)
- post-compulsory education
- youth issues
- learning difficulties/disabilities (with a focus on the physical impairments of blindness or deafness).

Such literature was accessed by searching academic journals, general citation indexes, electronic databases and gateways, literature abstracts, internet sites (including research and governmental sites), papers given at research conferences and newspapers. The searching was undertaken in two stages, first during June 2002, when the bulk of the studies were found, and then updated in January 2003 (and incrementally thereafter).

1 Keywords used

The keywords used for searching the literature base were agreed by the m-learning partner organisations as follows:

- handheld computer
- hand-held computer
- palmtop computer
- Personal Digital Assistant
- PDA
- Pocket PC

2 Inclusion/exclusion criteria applied

The inclusion criterion applied to identifying studies was that the study needed to have been undertaken since 1992, thus using a 10-year search base, where most literature would be situated in this emerging field. Any studies written in a language other than English, were excluded. It is recognised that research studies will have been undertaken with other portable technologies, such as laptop computers, notebook computers, sub-notebook computers and so on, but such technologies have been excluded from this review as they are not considered to be handheld.

3 Literature searches undertaken

The following are the academic journals and internet sites searched which focus on the use of IT and ICT.

(NB – for some journals noted in the Appendix it was not possible to access all issues as some were missing from the library or unavailable online etc – these have been marked with a †):

- Active Learning (1994+ Note: This journal began in 1994, and so the search base relates to literature 1994–2003. This notation (+) is used further below.)
- Alt-J (Association for Learning Technology Journal) (1993+)
- British Journal of Educational Technology
- Computer Assisted Language Learning
- Computer Education†
- Computers & Education
- Computers in the Schools (formerly called Information Technology and Learning)
- E.Learning Age (2001+)
- Education and Information Technologies (1996+)
- Education, Communication and Information (2001+)†
- Educational Computing and Technology (formerly called Educational Computing)†
- Educational Technology
- Educational Technology Research and Development (formerly called Education Communications and Technology)
- Information, Communication and Society
- Information Technology and Learning (ceased in 1993. This journal ceased in 1993, and so the search base relates to literature 1992–1993. This notation (journal ceased) is used further below.)
- Information Technology, Education and Society (2000+)†
- InterActive: Managing ICT in Schools (1995+)†
- Interactive Learning Environments (1995+)
- Journal of Computer Assisted Learning
- Journal of Educational Computing Research
- Journal of Educational Media
- Journal of Information Technology for Teacher Education (1992+)
- Journal of Interactive Learning Research (formerly called Journal of Artificial Intelligence in Education)
- Journal of Research on Computing in Education
- Learning and Leading with Technology (formerly called Computing Teacher)
- Technology and Learning

- Association for Learning Technology www.alt.ac.uk
- Becta (British Educational Communications and Technology Agency) www.becta.org.uk/index.cfm
- British Computer Society www.bcs.org.uk/
- Digital Library and Archives http://scholar.lib.vt.edu/
- From Now On (The Educational Technology Journal) www.fno.org/
- International Journal of Technologies for the Advancement of Knowledge and Learning (TechKnowLogia) www.techknowlogia.org/welcome.asp
- IPCT-J (International Computing and Technology Journal) http://jan.ucc.nau.edu/~ipct-j/
- National Education Computing Archive www.ultralab.ac.uk/projects/neca
- National Grid for Learning www.ngfl.gov.uk/
- National ICT Research Centre www.learninglab.org.uk/
- Tech Learning www.techlearning.com/
- The Information Network on Education in Europe (EURYDICE) www.nfer.ac.uk/eurydice/

The following are the academic journals and internet sites searched which focus on the acquisition of basic skills (which include literacy and numeracy):

- Basic Skills (1995+)
- Journal of Adolescent and Adult Literacy
- Journal of Literacy Research
- Literacy and Learning (1997+)†
- Literacy Today (1994+)
- Numeracy in Focus (1995+)†
- Written Language and Literacy (1998+)†

- Basic Skills Agency www.basic-skills.co.uk
- National Learning Network www.nln.ac.uk
- National Literacy Trust (and its research database) www.literacytrust.org.uk
- The Australian Journal of Language and Literacy (2001+)† www.alea.edu.au/pubs.htm#ajll

The following are the academic journals and internet sites searched which focus on the post-compulsory education sector:

- Adults Learning
- College Research Journal (1997+)
- Journal of Access Studies (to 1997)
- Journal of Further and Higher Education
- Journal of Vocational Education and Training
- Research in Post Compulsory Education (1996+)

- Scottish Journal of Adult and Continuing Education (1994+)
- Studies in Continuing Education
- Studies in the Education of Adults
- Vocational Training
- Widening Participation and Lifelong Learning (1999+)

- Adult, Career and Vocational Education Clearinghouse (ACVE) http://ericacve.org/searchinput.asp
- Campaign for Learning www.campaign-for-learning.org.uk/
- Further Education Funding Council for Wales (FEFCW) www.wfc.ac.uk/fefcw/index.html
- Further Education Resources for Learning (FERL) http://ferl.becta.org.uk/
- Learning and Skills Council www.lsc.gov.uk/
- National Advisory Council for Education and Training Targets (NACETT) www.countyweb.co.uk/cards/nacett/
- National Advisory Group for Continuing Education and Lifelong Learning (NAGCELL) www.niace.org.uk/Organisation/advocacy/NAGCELL/NAGCELL.htm
- National Centre for Vocational Educational Research, Australia (NCVER) www.ncver.edu.au/
- National Information and Learning Technologies Association (NILTA) www.nilta.org.uk/
- National Institute of Adult Continuing Education (NIACE) www.niace.org.uk/
- Planning Exchange (The Information Providers for Regeneration and Development) www.planex.co.uk/
- Scottish Further Education Funding Council (SFEFC) www.sfefc.ac.uk/
- Scottish Further Education Funding Unit (SFEU) www.sfeu.ac.uk/
- Standing Conference on University Teaching and Research in the Education of Adults (SCUTREA) www.scutrea.ac.uk/
- The Universities Association for Continuing Education (UACE) www.uace.org.uk/

The following are the academic journals and internet sites searched which focus on the youth issues:

- Children and Society
- Childright
- Health Education Journal
- International Journal of Adolescence and Youth
- Journal of Adolescence
- Journal of Youth and Adolescence
- Journal of Youth Studies
- Young People Now
- Youth Action
- Youth and Policy, the Journal of Critical Analysis
- Youth and Society

- British Youth Council www.byc.org.uk/
- National Youth Agency www.nya.org.uk/
- Pro Youth International (funded by the European Commission) www.alli.fi/euro/
- Scottish Youth Issues Journal† www.communitylearning.org/syij.asp
- The Foyer Federation www.foyer.net/
- The Prince's Trust www.princes-trust.org.uk/
- Wales Youth Agency http://www.wya.org.uk/
- YouthNet UK www.youthnet.org.uk/
- Youth Work on the Internet www.youth.org.uk/frame1.htm

The following are the academic journals and internet sites searched which focus on learning difficulties/disabilities (where the focus was on the physical impairments of blindness or deafness):

- Australian Journal of Education of the Deaf (formerly called Australian Teacher of the Deaf)†
- British Journal of Learning Disabilities
- British Journal of Special Education
- British Journal of Visual Impairment
- Canadian Teacher of the Deaf
- Deafness and Education (formerly called Journal of the British Association of Teachers of the Deaf)
- Deafness and Education International (formerly called Deafness and Education)
- European Journal of Special Needs Education
- Insight (formerly called Teacher of the Blind)
- International Journal of Inclusive Education (1997+)
- International Journal of Speech Technology (1995+)
- Journal of Deaf Studies and Deaf Education (1996+)
- Journal of Learning Disabilities
- Journal of Research in Special Educational Needs (2001+)
- Journal of Visual Impairment and Blindness
- Learning Disabilities Research and Practice
- Teaching English to the Deaf†
- Technology Update (by the Sensory Aids Foundation)†
- The New Zealand Journal for Teachers of the Deaf

- AbilityNet www.abilitynet.co.uk/
- Blindness Resource Centre www.nyise.org/deaf.htm
- British Computer Association of the Blind www.bcab.org.uk/
- British Deaf Association www.britishdeafassociation.org.uk/
- Disability/ Exceptionality Web Resource Library www.asri.edu/CFSP/brochure/library.htm
- National Bureau for Students with Disabilities (SKILL) www.skill.org.uk/
- Royal National Institute for Deaf People www.rnid.org.uk/
- Royal National Institute for the Blind (including publications Eye Contact and Visability)† www.rnib.org.uk/

- Scope www.scope.org.uk/
- Technology for Disabilities Information Centre www.techdis.ac.uk/
- The Canadian National Institute for the Blind Library www.cnib.ca/library/
- The Deaf Resource Library www.deaflibrary.org/

The following are the general citation indexes, electronic databases and gateways which were searched:

- Arts and Humanities Citation Index
- British Education Index (BEI) www.leeds.ac.uk/bei
- British Humanities Index (BHI Net)
- British Library Electronic Table of Contents Online (ZETOC) http://zetoc.mimas.ac.uk/index.html
- Educational Resources Information Centre (ERIC)
- Joint Information Systems Committee (JISC) www.jisc.ac.uk/
- National Information Services and Systems (NISS) www.niss.ac.uk/
- Periodicals Contents Index (PCI)
- Social Science Information Gateway (SOSIG) http://sosig.ac.uk/

The following are the literature abstracts which were searched:

- Contents Pages in Education
- Educational Research Abstracts
- Educational Technology Abstracts
- Special Educational Needs Abstracts

The following are other UK research/governmental/miscellaneous organisations which were searched:

- DENI (Department for Education, Northern Ireland) www.deni.gov.uk/
- DfES (Department for Education and Skills) www.dfes.gov.uk/index.htm
- Learning and Skills Development Agency's library database www.lsda.org.uk/
- National Assembly for Wales www.wales.gov.uk/
- National Foundation for Educational Research (NFER) www.nfer.ac.uk/
- Scottish Executive Education Department www.scotland.gov.uk/who/dept_education.asp
- Scottish Executive Enterprise and Lifelong Learning Department (SEELLD) www.scotland.gov.uk/who/elld/
- University for Industry/learndirect www.ufi.com

The following are European organisations which were searched:

- European Association for Research on Learning and Instruction www.earli.eu.org/
- European Centre for the Development of Vocational Training) (CEDEFOP) www.cedefop.eu.int/

- European Commission Community Research and Development Information Service (CORDIS) www.cordis.lu/en/home.html
- Organisation for Economic Co-operation and Development (OECD) www.oecd.org/
- United Nations Educational, Scientific and Cultural Organisation (UNESCO) www.unesco.org/

The following are research bodies which were searched (principally for papers presented at annual research conferences):

- American Educational Research Association www.aera.net/
- Association for Learning Technology (Alt-C) www.shef.ac.uk/alt
- Australian Association for Research in Education www.aare.edu.au/index.htm
- British Educational Research Association www.bera.ac.uk/
- European Educational Research Association www.eera.ac.uk/
- European Information Society Technologies' Conferences www.cordis.lu/ist/ Link with European Commission CORDIS website at www.cordis.lu noted earlier under 'European organisations'
- Online Educa www.online-educa.com/
- Scottish Council for Research in Education www.scre.ac.uk/
- The New Zealand Council for Educational Research www.nzcer.org.nz/search/Searchsite.htm

The following are online newspapers which were searched:

- British Newspaper Index (BNI) (1995+)
- Times Educational Supplement www.tes.co.uk/
- Times Higher Educational Supplement www.thes.co.uk/

The following are internet search engines which were used to search for 'grey' literature (ie literature produced by academics, business and industry in print and electronic formats, but not controlled by commercial publishers, eg on the internet) where the main emphasis is on finding research studies noting young people's experiences of mobile technologies)

- AltaVista uk.altavista.com/
- Google www.google.com/search
- Yahoo www.yahoo.com/

GLOSSARY

Beaming	Using infra-red communications to exchange data between two PDAs
EPOC™	Operating system of the now discontinued Psion palmtop computers (see Symbian)
'Hotsyncing' (HotSync®)	The primary method for transferring data and programs between a PDA and a PC – the PDA is inserted into a special cradle, then files are automatically 'synchronised' – ie compared so that older ones on one device are replaced by newer ones on the other device
Infra-red transmission	Infra-red transmission refers to energy in the region of the electromagnetic radiation spectrum at wavelengths longer than those of visible light, but shorter than those of radio waves. Correspondingly, infrared frequencies are higher than those of microwaves, but lower than those of visible light. Infra-red is used in a variety of wireless communications, monitoring and control applications, eg home entertainment remote-control boxes, wireless local area networks, links between notebook computers and desktop computers, intrusion detectors etc
Multitasking	A feature of an operating system which allows more than one program to run at the same time
Operating system (OS)	The base software of a computer device. Three OSs currently compete in the palmtop marketplace: PalmOS®, PocketPC and Symbian™
PalmOS®	The operating system used by the majority of PDAs, particularly the Palm brand. Features 'Graffiti®' handwriting input system
Personal Digital Assistant (PDA)	A small hand-held computer typically providing a calendar, contacts address list, calculator and notetaking applications. It may also include other applications, eg a web browser and a media player. Small keyboards and pen-based input systems are most commonly used as input systems
PocketPC	Operating system by Microsoft for handheld computers

Symbian™	A consortium of PDA and mobile phone manufacturers, which use the Symbian operating system [www.symbian.com] (formerly called Psion EPOC)
Tablet PC	A Tablet PC is a wireless PC that allows a user to take notes using natural handwriting with a stylus, digital pen, or on a touch screen. It is similar in size and thickness to a paper notepad. There are two formats, a convertible model with an integrated keyboard and display that rotates 180 degrees and can be folded down over the keyboard, or a slate style together with a removable keyboard. The user's handwritten notes, which can be edited and revised, can also be indexed and searched or shared via e-mail or mobile phone
Tamagotchi™	Tamagotchi is a tiny virtual reality pet creature, and were developed in Japan in 1996 as an LCD display inside a small plastic egg-shaped keychain. The purpose of the game is to care for a cyberpet while it is on this planet before it returns to its home planet. The cyberpet is always turned on, and such care involves different aspects as it grows from an egg through to old age, eg it has to be fed, played with, allowed to rest, and a measure of discipline exerted related to weight change etc. If constant care is given, the cyberpet should grow into a healthy, well-behaved adult, if it is ignored it will grow ill. Different Tamagotchi have different shapes and personalities
Windows CE® OS (Compact Edition)	This is a version of the Microsoft Windows operating system developed for use with handheld PCs and other electronic devices

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